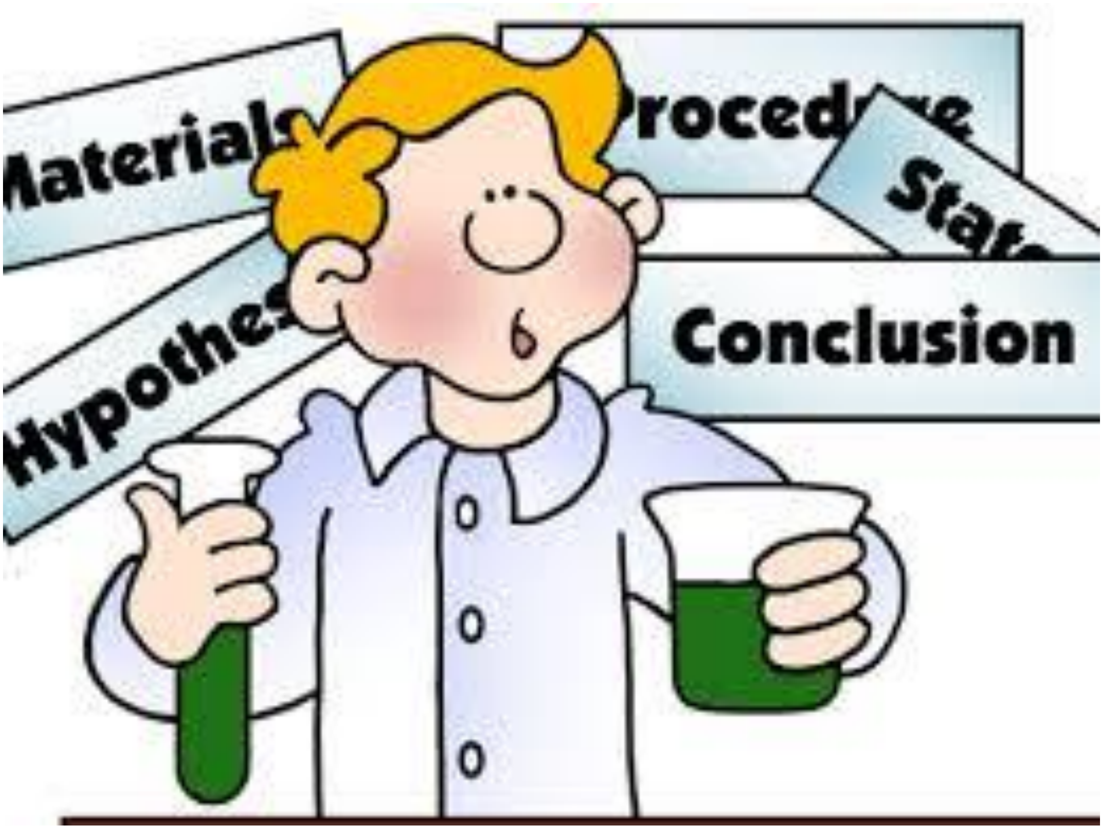
BTEC Applied Science
Unit 3 – Science Investigation Skills Transition Booklet



Key Concepts to Unit 3
Learning Aims A-C

Name: ....

Learning Aim A – Planning an investigation

Writing a hypothesis for investigations – A1

Hypothesise are made as a starting point for an investigation and can be changed as further investigations are carried out and the subject is taken forward.

A hypothesis is a prediction (often an assumption based on current knowledge and evidence) of what you expect to see in your results.

A null hypothesis is a prediction (where you might not expect to find a particular trend or pattern) which states that any recorded/observed differences between two or more data sets is due to chance. A null hypothesis is tested by analysing results statistically. If the null hypothesis is rejected, this indicates that there is a statistically significant difference (which can be explored/explained with science).

NOW YOUR TURN

A1 – Writing a Hypothesis and Null Hypothesis

1. How could you write a hypothesis to the following experiment:

Metal powers react with copper sulphate solution in displacement reactions to produce a new metal salt. This reaction releases heat energy which be measured and used to determine the reactivity of the metal from the periodic table.

2. How could you write a null hypothesis to the following experiment:

Dove soap and Dettol soap are both usefully for hand-washing. Paper discs can be diffused/soaked with different soap solutions and placed onto agar plates which have been inoculated with bacteria. After incubating the plates, clear areas of no bacterial growth can be measured (zones of inhibition). The larger the zone of inhibition, the greater the effect of each soap on killing bacteria.

Use of equipment, techniques and procedures – justification – A2

Precision – the precision of equipment is inversely proportional to the unit size, i.e. the smaller the unit, the more precise it is.
(In length measurements, µm units are more precise than mm units – because 1mm = 1,000µm)

Accuracy – the accuracy of equipment is dependent upon the percentage error.
This can be calculated using the following formula:

$$\text{Percentage Error} = \frac{\text{Absolute Error}}{\text{Measurement}} \times 100\%$$

Absolute error is an accuracy equal to +/- half of the smallest unit marked on the scale of the measuring device.
(A ruler measuring only in 1cm intervals is less accurate than a ruler measuring in 1mm intervals – 1cm = 0.5cm or 5mm is absolute error, 1mm = 0.5mm is absolute error)

NOW YOUR TURN

A2 – Justifying equipment, A3 – Health and safety, A4 – Variables and A5 – Methods

1. Compare the term 'precision' when choosing equipment vs. analysing results.

2. Put these units of measurement in order of their precision.
mm, m, cm, nm, km, μm

3. Comment on the precision of these results.
10, 12, 11, 18, 19, 20

4. Compare the term 'accuracy' when choosing equipment vs. analysing results.

5. Calculate the percentage error for the following measurements:

a. A 30cm has 0.1cm divisions . A plant leaf measures 26cm.

b. A balance reading goes to 0.01g. A precipitate weighs 5.68g

c. A measuring cylinder has 1ml divisions. A collection of rainwater goes to 67ml.

d. A thermometer measures to 1°C. When a temperature rise is measured, two separate readings are taken so both readings could be out. A temperature rise of 7°C was measured.

6. Describe how using a burette instead of a measuring cylinder for volume can improve accuracy.

7. You carry out an investigation to study the effect of temperature on the rate of reaction between magnesium ribbon and hydrochloric acid. Complete a risk assessment including the following:

a. Identify two hazards

b. Describe the risks associated with these two hazards

c. What can you do to minimise these two risks

8. For the experiment described in Q7, identify:

a. The independent variable

b. The dependent variable

c. The control variable(s)

d. Any confounding variable(s)

9. Describe how the reliability of an investigation can be increased.
(Refer to anomalous results in your answer).

10. Describe how the validity of an investigations conclusions can be upheld.

Health and Safety – A3

Hazard – something that has the potential to cause harm.

Risk – the level of harm that could be caused by a hazard, AND, the chances of it happening (this depends on the method).

Risk assessment – identifying hazards, describing the risk, describing precautions.

Variables – A4

Independent – The variable chanced by the scientist

Dependent – The variable affected/changed by the independent variable and the variable measured.

Control – The variables which need to be kept constant as they would others impact on the dependent variable.

Confounding – The variables which will inevitably have an impact on the dependent variable and which can’t be easily controlled.

Methods – A5

Methodologies should always be written as step-by-step instructions, in the third person past tense.

Standard operating procedures (SOP) – these are applicable to most scientific investigations and comes under Good laboratory practice (GLP). It includes detail on how tests are carried out, how chemicals are handled and stored, how waste is disposed of, how equipment is used and maintained and the use of Personal Protective Equipment (PPE).

Taking measurements – it is important to know how the dependent variable is going to be measured (the equipment), where it’s going to be recorded (in a results table) and what range/intervals are to be taken.

Accuracy – the accuracy of results is based on their closeness to the true/actual values.

Precision – the precision of results is based on the closeness of repeat values.

Reliability – the reliability of results is how trustworthy they are. This can be impacted by their reproducibility (can someone else do the experiment and get the same results), repeatability (can an individual do the experiment again and get the same results).

Validity – the validity of results and any conclusions drawn depends on whether the control variables were maintained.

NOW YOUR TURN

A4 – Variables

Complete the table below to identify the variables in each investigative scenario

Investigation	Independent variable	Dependent variable	Controlled variables
How does the weight on the end of a spring affect its stretching?			
How does the length of a pendulum affect the time taken to swing?			
How does temperature affect how much salt dissolves in water?			
Does temperature affect how quickly sugar dissolves in tea?			
Does acid strength affect the rate of reaction with calcium carbonate?			
Which is the better detergent surf or Ariel?			
How does the soil affect the growth of parsley?			
How does light intensity affect the rate of photosynthesis?			

Learning Aim B – Data collection, processing and analysis

Collection of results/data – B1

Accuracy – the accuracy of results depends on the equipment/technique used to record/observe them. You need to use equipment correctly to get accurate results – i.e. reading volumetric values in a burette from the bottom of the meniscus and at eye level.

Reliability and Anomalous results – the reliability of data collection depends on taking repeat readings for each independent variable interval. If two readings are the same they are reliable. If they are not the same, a third (repeat) reading is needed. A result which does not lie consistently with the rest is an anomaly (an anomalous result) which can be discarded/ignored. The results that are consistent can be used to make a reliable mean/average.

Qualitative data – Observations are often qualitative (descriptive) and give categorical data (where there is a set amount of possible outcomes).

Quantitative data – Measurements/readings/recordings are quantitative (numerical) and give continuous or discrete data (where there is no set amount of possible outcomes).

NOW YOUR TURN

B1 – Collection of results and B2 – Processing results

1. What is the difference between continuous and categorical data?

2. What is the difference between a result and an observation?

3. Record the following data in a suitable table.
The effect of temperature on the time taken for fly eggs to hatch.
5°C = 230 hours, 10°C = 90 hours, 11°C = 70 hours, 13°C = 50 hours, 17°C = 30 hours, 19°C = 25 hours

4. Draw of suitable graph of the results.

Portraying results/data – B2

Tabulating data – tables are used to record:
1. Raw data (both qualitative and quantitative data can be recorded in tables but must be in separate tables if collected together in one experiment).
2. Processed data (quantitative data that has been mathematically/statistically manipulated

Tip 1: Draw your table **BEFORE** you collect your raw data as you will need to fill it in as your go along

to make it more comparable – i.e. means and rates).

Yeast (enzyme) concentration / mg cm^{-3}	Time taken to collect 30 cm^3 of oxygen / s		
	Repeat 1	Repeat 2	Repeat 3
5	33	33	32
9	24	26	25
14	17	20	16
18	13	13	15
23	12	11	12
28	11	11	13

Table 1 is an example of raw data

Table 1: Time taken to collect 30 cm^3 of oxygen for different concentrations of yeast (enzyme) mixed with hydrogen peroxide solution.

Tip 2: Give your table a clear and informative heading which tells you what the table is about

Tip 5: **Record** the **independent variable** (remember **I** choose!) in the 1st column. This is the variable you are controlling, in this case yeast (enzyme) concentration.

Tip 3: Draw your table using a ruler

Tip 4: Units are placed **only** in the column heading, after a solidus (forward slash): **/ s**

Use the correct **SI units**

Tip 6: **Record** the **dependent variable** in the 2nd column. This is the variable you are measuring, in this case time taken to collect a certain volume of oxygen.

Note this column has been **subdivided** into 3 so that

Table 2 is an example of processed data

Table 2: Mean time taken to collect 30 cm^3 of oxygen for different concentrations of yeast (enzyme) mixed with hydrogen peroxide solution and mean rate of oxygen production.

Tip 7: The **mean time** has been worked out by adding the time from the 3 repeats and dividing by 3. Show it to the same number of decimal places as the data which was used to calculate it.

Tip 8: The **mean rate** has been worked out by dividing 30 cm^3 by the time taken to collect it. **REMEMBER**: rate is always something per unit time (so divide by time).

Yeast (enzyme) concentration /mg cm^{-3}	Mean time taken to collect 30 cm^3 of oxygen / s	Mean rate of oxygen production / cm^3 s^{-1}
5	33	0.91
9	25	1.20
14	18	1.67
18	14	2.14
23	12	2.50
28	12	2.50

Tip 9: In some experiments, all you record is the time taken for something to happen.

In these experiments, the rate = 1/time.

For example, if it takes 10 seconds for a reaction to happen:

Tip 10: You can include raw and calculated data in ONE table!

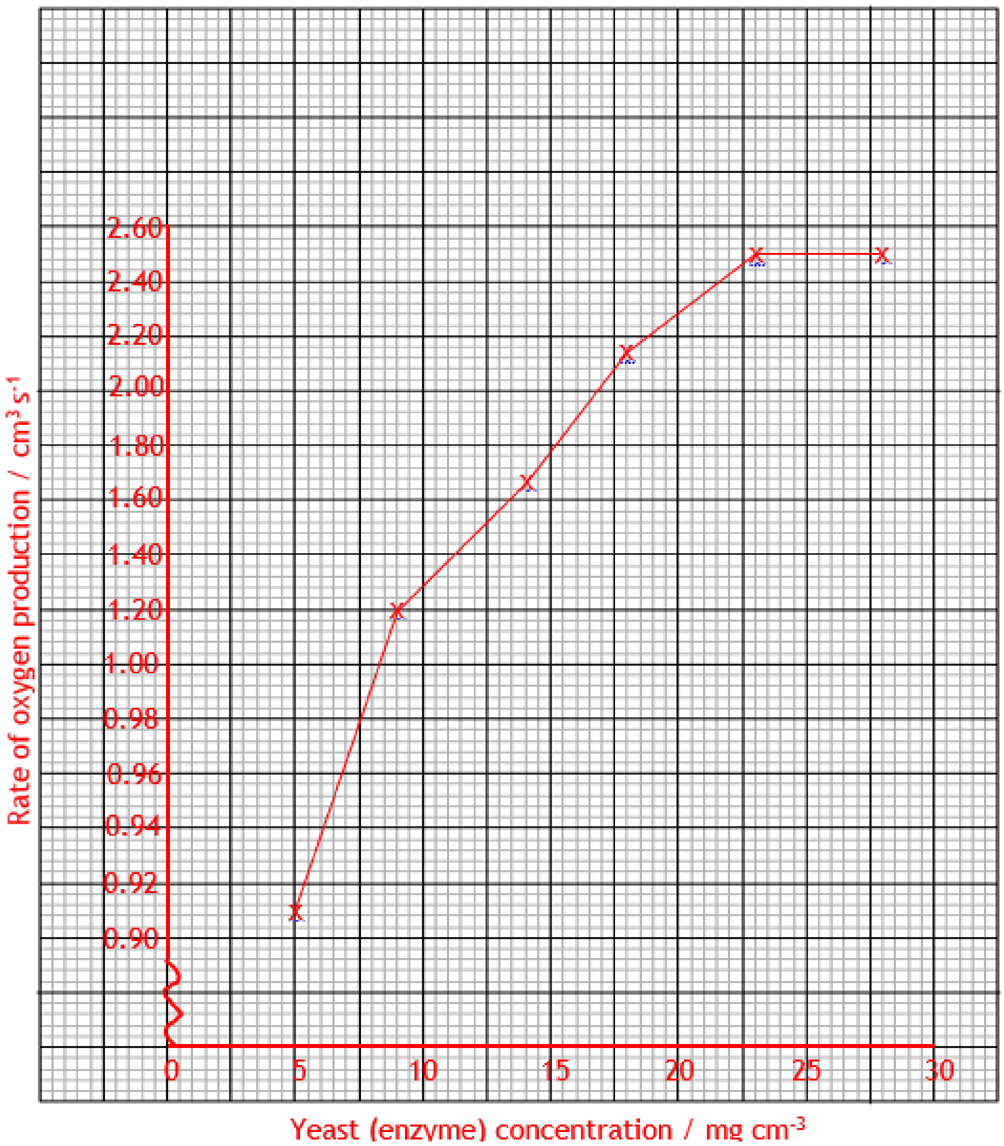
Table 1: Time taken to collect 30 cm^3 of oxygen for different concentrations of yeast (enzyme) mixed with hydrogen peroxide solution with calculated means and rates.

Yeast (enzyme) concentration /mg cm^{-3}	Time taken to collect 30 cm^3 of oxygen / s			Mean time taken to collect 30 cm^3 of oxygen / s	Mean rate of oxygen production / cm^3 s^{-1}
	Repeat 1	Repeat 2	Repeat 3		
5	33	33	32	33	0.91
9	24	26	25	25	1.20
14	17	20	16	18	1.67
18	13	13	15	14	2.14
23	12	11	12	12	2.50
28	11	11	13	12	2.50

Graphically portraying data – this be done in line graphs or bar graphs/charts

LINE GRAPHS – for continuous data in the independent variable

Graph showing relationship between rate of oxygen production and yeast (enzyme) concentration during breakdown of H_2O_2 by catalase

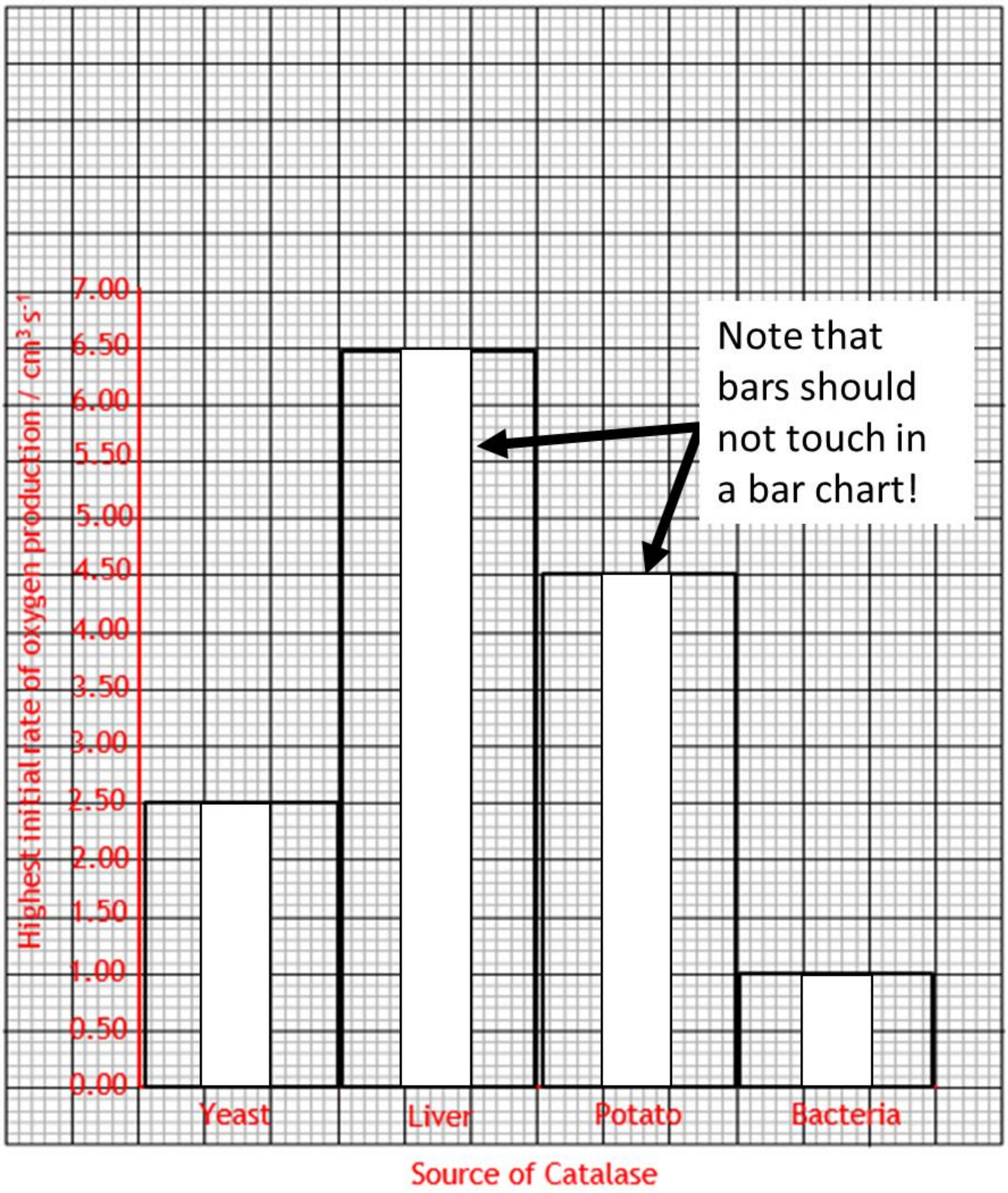


LINE GRAPH TIPS

- Give your graph a full heading
- Label BOTH axes with the quantity being measured and the units.
- Separate the label and units with a solidus: /s^{-1}
- Spread the data points on a graph as far as possible without using scales that are difficult to deal with, such as multiples of 3, 7, 11 etc.
- *Consider the maximum and minimum values of each variable.*
- 0.0 does not have to be included as a data point (though in this example it could have been included if you had tested to show that without yeast, no oxygen is produced - i.e. if you had included a control in your experiment).
- The **plots** should cover **at least half** of the grid supplied for the graph.
- Plot data points carefully and accurately using a X
- Join points carefully using a curve, line of best fit or dot-to-dot line using a sharp pencil.
- For lines of best fit there should be as many points on one side of the line as the other. Often the line should pass through, or very close to, the majority of plotted points.

BAR GRAPHS – for discrete/categorical data in the independent variable

Graph showing the highest initial rate of reaction for Catalase taken from different cellular sources.



BAR GRAPH TIPS

- Give your graph a full heading
- Label BOTH axes with the quantity being measured and the units.
- Separate the label and units with a solidus: $/s^{-1}$
- Spread the data points on a graph as far as possible without using scales that are difficult to deal with, such as multiples of 3, 7, 11 etc.
- The **plots** should cover **at least half** of the grid supplied for the graph.
- Plot data points carefully and accurately using a ruler for a straight horizontal line for each bar
- Don't shade in the bars

Processing results/data – B2

Calculations with results/data need to be done including:

1. Percentage
- (Value/Total) X100
- eg: 37/100 on a test = 37%

2. Percentage change
- (Original-New value)/Original X100
(Homer Simpson! DOH! Difference/Original X Hundred
- eg: 78/100 on next test so (37-78) / 78 X100 = 110.81% increases

3. Mean
- All values added together / number of values
- 37, 42, 45, 35, 40 (added together = 199) (divided by 5 for number of values) = 39.8

4. Standard deviation
- 'The spread of data about the mean'.
- Gives an indication of how spread out the results are
- $$s = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}}$$
- S = standard deviation
- ∑ = Sum of
- X = one data/result value
- $\bar{X}$ = mean/average
- n = sample size
- eg:
X = 37, 42, 45, 35, 40
$\bar{X}$ = 39.8
Subtract each number by the mean and square the result
$(37-39.8)^2$, $(42-39.8)^2$, $(45-39.8)^2$, $(35-39.8)^2$, $(40-39.8)^2$
Add up all these values
= 62.83
Divide by one less than the sample number
=62.83 / (5-1) = 15.7075
Square root this number to get the final answer of Standard Deviation
= √15.7075
= 3.96

5. Standard error
- Errors bars of standard deviation applied (± plus and minus) to the mean on a graph
- Can be used to determine if there is a scientifically significant difference between the mean/average of two or more data sets (see more later)…

$$SE_{\bar{x}} = \frac{s}{\sqrt{n}}$$

- eg: $SE_{\bar{x}}$ = 3.96 / √5 = 1.77

6. Chi-squared test
- Determines if there is a significant difference between expected/predicted results and observed/actual recorded results.
- $X^2 = \sum \frac{(O-E)^2}{E}$
- eg:

Student	Test score %	
	Observed (O)	Expected €
1	76	70
2	56	60
3	60	68
4	64	50

(Observed – Expected)^2 then / expected for each data set (student)
= 0.51, 0.26, 0.94, 3.92
Add these values together = X^2
= 5.63
The value of X^2 is compared to a 'Critical value' in order to determine if there is a significant difference between expected and observed results or whether any differences are just due to chance.
See more later…

7. t-test, correlation analysis
- Determines if there is a significant difference between different samples of data (unmatched pairs / unpaired data) which have been collected from separate experiments.
- Uses mean/average with standard deviation in standard error calculation:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

-
- eg:

Student	English test score /100	Maths test score / 100
1	90	60
2	87	70
3	68	65
4	70	52
Mean	78.75	61.75
Standard deviation	11.35	7.68

- Difference in means = 78.75 – 61.75 = 17
- Standard errors added together ($11.35^2/4 + 7.68^2/4$) = (32.21 + 14.75) = 46.96
- Square root the sum of standard errors = $\sqrt{46.96}$ = 6.85
- Difference in means / square root of sum of standard errors = 17/6.85 = 2.48
The value of t-test is also compared to a 'Critical value'…
See more later…

8. Use of formula and conversion of units
- You may be given formula which you then need to use and apply to a given question
- Many formula are related to Physics topics (i.e. calculating electrical and mechanical power)
- You may be asked to calculate rate of reaction (especially for the Biology enzymes topic)
Rate is calculated as 1/time (sec^{-1}) or amount produced/time taken (example units could be cm^3/min^{-1})

8. Standard form
- You may be asked to demonstrate your answers to mathematical equations in standard form.
- i.e. For decimals: 0.0005 = $5X10^{-4}$
- i.e. For large numbers: 600000 = $6X10^5$

9. Converting between units
- You may be asked to convert between standard units (SI units)
- i.e. 1mm = 1,000µm

NOW YOUR TURN

B2 – Processing results

Table 1 Numbers of patients, separated according to age and gender, reporting with different conditions at a hospital clinic

Condition	Males				Females			
	Age (years)				Age (years)			
	0-19	20-39	40-59	60-79	0-19	20-39	40-59	60-79
Deformity present at birth	4	0	1	0	14	0	0	
Fracture of arm bone	49	12	5	2	13	3	1	7
Fracture of upper leg bone	3	3	1	10	2	2	1	32
Fracture of lower leg bone	7		4	0	9	2	5	4
Fracture of ankle	7	8	6	2	1	7	5	6
Deformed toes	0	2	6	5	4	17	39	25
Arthritis	0	11	46	83	0	4	49	167
Unspecified joint problems	13	52	52	33	6	45	72	71
Unspecified back problems	3	56	74	48	5	65	141	64
Other conditions		117	184	97	62	107	148	147
TOTAL	140	270	379	280	116		461	523

1. Complete the missing data in the table above (4 marks)

2. (a) For female patients aged 20-39 only, calculate the percentage who had 'fracture of the arm bone'. Give your answer to 2 d.p. (2 marks)

(b) For male patients of all ages, calculate the percentage who had 'unspecified back problems'. Give your answer to 2 d.p.

(2 marks)

NOW YOUR TURN

B2 – Processing results

Table 1 Numbers of patients, separated according to age and gender, reporting with different conditions at a hospital clinic

Condition	Males				Females			
	Age (years)				Age (years)			
	0-19	20-39	40-59	60-79	0-19	20-39	40-59	60-79
Deformity present at birth	4	0	1	0	14	0	0	
Fracture of arm bone	49	12	5	2	13	3	1	7
Fracture of upper leg bone	3	3	1	10	2	2	1	32
Fracture of lower leg bone	7		4	0	9	2	5	4
Fracture of ankle	7	8	6	2	1	7	5	6
Deformed toes	0	2	6	5	4	17	39	25
Arthritis	0	11	46	83	0	4	49	167
Unspecified joint problems	13	52	52	33	6	45	72	71
Unspecified back problems	3	56	74	48	5	65	141	64
Other conditions		117	184	97	62	107	148	147
TOTAL	140	270	379	280	116		461	523

(c) In data from the previous year, there were 18 women aged 60-79 who had 'deformed toes'. Calculate the percentage increase in this year's data. Give your answer to 2 d.p.

(2 marks)

3. Look at the data and draw some conclusions from it (the first one has been done for you).

a) Fractures of arm bones are most common in the 0-19 age group for males and females

b) ……….

c) ……….

d) ……….

e) ………. (4 marks)

NOW YOUR TURN

B2 – Processing results

1. Work out the standard deviation for the following data.

The effect of a fertiliser on plant growth was measured.

Plant sample	Increase in plant growth (cm)
1	150
2	125
3	132
4	144
5	158

2. Work out the standard deviation for the following data.

The effect of an antibiotic on zone of inhibition in bacterial agar plates was measured.

Antibiotic sample	Zone of inhibition (mm)
1	60
2	45
3	55
4	70
5	52

3. Work out the chi-squared value for the following data.

The expected results from a Biology test vs. the observed results are shown.

Student	Test score %	
	Observed (O)	Expected (E)
1	50	80
2	45	70
3	54	90
4	46	75

NOW YOUR TURN

B2 – Processing results

4. Work out the chi-squared value for the following data.

The expected results from a Maths test vs. the observed results are shown.

Student	Test score %	
	Observed (O)	Expected (E)
1	60	50
2	43	60
3	32	40
4	66	45

5. Work out the t-test value for the following data.

The amount of oxygen collected from the breakdown of hydrogen peroxide using catalase from liver cells vs. yeast cells is shown.

Sample	Oxygen collected from liver cells (cm^3)	Oxygen collected from yeast cells (cm^3)
1	40	26
2	45	24
3	38	20
4	42	29

6. Work out the t-test value for the following data.

The amount of glucose released from the breakdown of glycogen vs. starch.

Sample	Glucose released from glycogen (mg)	Glucose released from starch (mg)
1	15	17
2	17	19
3	19	20
4	16	18

Learning Aim C – Drawing Conclusions and Evaluation

Describing data/result trends – C1

You will be asked to describe trends in your own results and/or the results given to you by another experiment.
For this you must look at the data in your results table and/or graph and describe any relationships shown.

Possible relationships using continuous data include:
- Positive correlation: where an increase in the independent variable causes an increase in the dependent variable
- Negative correlation: where an increase in the independent variable causes a decrease in the dependent variable
- Plateau: where an increase in the independent variable causes no increase or decrease in the dependent variable (there is no change).
- You can comment on the proportionality of the correlation by referring to the level of proportionality (i.e. a very steep increase or decrease has a high level of direct proportionality, or if one variable doubles causing the other to half shows inverse proportionality).
- You can comment on the strength of the correlation by referring to where the data points are in relation to the line of best fit (i.e. lots of points close to the line of best fit gives a strong correlation)

When describing relationships with discrete/categorical data, you will need to assess the data given – try grouping results that are similar against those that are different.

Comparing primary and secondary data – C1

Primary data = your data
Secondary data = someone else's data

You may be asked to compare primary data and secondary data
- Similarities
- Differences

You may be asked to use data (primary or secondary) to predict an untested result.
i.e. Results 2, 5, 8, 11. The next likely result is 14 because there is a trend of +3…

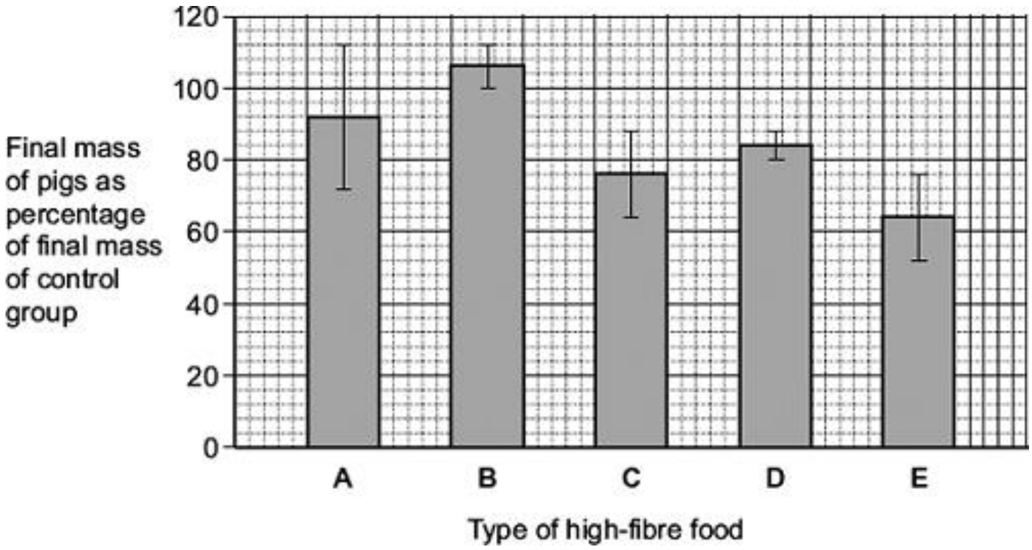
Drawing valid conclusions using data – C1

After carrying out statistical tests (standard deviation and standard error, X2 and t-test), you may be asked to make some valid conclusions about differences between data – i.e. determine whether any differences in results are statistically significant (which can therefore be explained scientifically) or whether any differences in results are just due to chance/random error.

Answering a null hypothesis with standard deviation/standard error:
When comparing averages between data sets, standard deviation or standard errors can be applied to give error bars on a bar chart.
If error bars between two data sets overlap, there is no significant difference between them, any differences in the average are due to chance – null hypothesis can be accepted.
If error bars between two data sets don't overlap, there is a significant difference between them – null hypothesis can be rejected.

For example:
Pigs require a mixture of fibre and protein in their food. The greater the ratio of fibre to protein, the less the food costs.

Scientists took five large groups of pigs. They fed each group a different high-fibre food. Each of the foods contained fibre from different plant species, but they all had the same energy content. The scientists fed a control group of pigs a low-fibre food with the same energy content. After 10 days, the scientists compared the masses of the pigs fed on high-fibre food to those fed on low-fibre food.
The graph shows the results of the investigation. The bars represent ±2 standard errors of the mean.



A farmer saw these results and concluded that he should replace his pigs' usual food with food B. Evaluate this conclusion.

Template answer:
- Food B produces greater mass than the control / greater than 100%
- But error bars for B mean show that B is not significantly different from control / from 100%
- And A and B error bars overlap
- So B is not significantly better than A
- However the experiment only ran for 10 days
- There is no information about cost.
- Experimental conditions / breed of pig could be different

<u>Answering a null hypothesis with chi-squared (X^2) and critical value comparison:</u>
When comparing the values of observed vs. expected results, X^2 can be calculated and compared to a 'critical value' in order to determine if there is significant difference / chance difference.

Critical values are obtained by looking at a table of critical values and using the one which is specific to the context – this is based on a p-value (probability value) of 0.01-0.05 or 1-5% in Science and a degree of freedom = n-1.
The p-value = 0.05 states that our critical value to accept chance occurring in the results is limited to 5%. So we need to be 95% confident of any significant difference in results.
The degree of freedom is dependent on the sample size (n) – 1.
- **Accept** the null hypothesis (there is no significant difference / difference is due to chance) if X^2 is **less than** the critical value.
- **Reject** the null hypothesis (there is significant difference) if the X^2 is **equal to/more than** the critical value.

For example:
16 woodlice were placed in a choice chamber where there are four different environmental conditions.

Environment	Observed results (O)	Expected results (E)	$(O - E)^2$	$\frac{(O - E)^2}{E}$
Dry, light	0	4	16	4
Dry, dark	5	4	1	0.25
Damp, light	4	4	0	0
Damp, dark	9	4	25	6.25

$\chi 2 = 10.5$

Table of χ^2 probabilities					
Degrees of freedom (n-1)	← *Chance* -- Probability -- *Not Chance* → (that the difference between O and E is due to chance)				
	0.2 20%	0.1 10%	0.05 5%	0.02 2%	0.01 1%
1	1.64	2.71	3.84	5.41	6.64
2	3.22	4.61	5.99	7.82	9.21
3	4.11	6.25	**7.82**	9.84	11.35
4	5.59	7.78	9.49	11.67	13.28

Critical value = 7.82

Reject the null hypothesis – the X^2 is greater than the Critical value, so the difference between observed and expected is significant.
There is less than 5% probability that the difference is due to chance.
There is 95% confidence that the difference is significant.

<u>Answering a null hypothesis with t-test and critical value comparisons:</u>
The approach is very similar to the X^2 test analysis.
A separate critical value table is used for the t-test, however the same value of p is often used (0.05 or 5%).
To work out degrees of freedom you must: (n1 + n2) – 2
Comparison of t-test result to p-value allows null hypothesis to be accepted or rejected.
- **Accept** the null hypothesis (there is no significant difference / difference is due to chance) if t-test is **less than** the critical value.
- **Reject** the null hypothesis (there is significant difference) if the t-test is **equal to/more than** the critical value.

NOW YOUR TURN

C1 – Interpretation / analysis of data

1. Compare the terms 'primary data' and 'secondary data'

2. An investigation was done to measure the effect of temperature on the rate of reaction for 3 different enzymes.
Predict the missing results.

Temperature °C	Rate of reaction (s^{-1})		
	Enzyme 1	Enzyme 2	Enzyme 3
5	4	7	6
10			15
15	12		
20	16	28	33
25		35	
30	24		51
35		48	

3. What is the difference between a positive correlation and a negative correlation?

4. What does a plateau of results indicate?

5. What is the difference between results showing direct proportionality and those showing inverse proportionality?

6. How do the results of a strong correlation compare to a weak correlation when viewing a line of best fit on a graph?

NOW YOUR TURN

C1 – Using Statistics to answer a null hypothesis

1. Draw a bar chart to show the following data and answer the null hypothesis: "There is no significant difference between the type of fertiliser used on the growth of plants".

Fertiliser	Mean increase in plant growth	Standard deviation
A	40	6
B	30	6
C	15	8
D	60	10

2. Work out chi-squared for the data and answer the null hypothesis: "there is no significant difference between the observed frequency and the expected frequency of fish".

A section of river was searched for 4 types of freshwater fish. It was expected that there would be equal numbers of each type of fish collected – a total of 40 fish were collected.

15 were roach, 15 were perch, 6 were pike and 4 were bream.

The critical value for 3 degrees of freedom (n-1) at a p-value of 0.05 = 7.82.

Evaluations – C2

Evaluations consist of several areas:

- Errors:
Mistakes in carrying out method (human error).
Inherent percentage error in the equipment (systemic error).

- Anomalous results:
An explanation of how anomalies occurred.
A description of how future anomalies can be avoided (carrying out repeats and calculating averages).

- Improvements/Alternatives:
Modifications which would improve the reliability, accuracy or precision of results.
Modifications which would reduce/remove errors and anomalies.

- Extensions:
Additional experiments/steps in method which would give more data.
Could expand on the range and/or intervals of the current independent variable.
Could change the independent variable (swop one of the control variables to make a new independent variable).